APPARATUS FOR AND METHOD OF THIXOCASTING CAST IRON

[0001] TECHNICAL FIELD

[0002] The present invention relates to an apparatus for and a method of thixocasting a cast iron and, more particularly, to an apparatus for and a method of thixocasting a cast iron, that prevent the mixing of scale thereby to obtain sound iron castings having good mechanical properties.

[0003] BACKGROUND ART

[0004] Thixocasting process, in which semi-molten billets, in such a state as solid and liquid phases coexist, formed by heating cast iron are injected into a mold constituted from dies, is capable of manufacturing a part that has a smaller wall thickness and more complicated shape than are possible with the conventional iron casting processes. The thixocasting process can manufacture a part near net shape that has substantially no casting defects such as shrinkage cavity, and is therefore regarded as a promising new iron casting method.

[0005] However, the thixocasting process of the prior art has such a problem that, when cast iron is heated so as to turn into a semi-molten state, scale formed on the material surface may mix into the casting, thus resulting in a defect and making it difficult to obtain sound castings on a stable basis.

[0006] There has also been such a technical problem that the thermal load on the die may cause melting loss and/or cracks when casting semi-molten cast iron that is a material of high melting point. The melting loss and/or cracks tend to occur at the end of an injection path that runs from an injection sleeve to a mold cavity, namely at a

gate provided at the entry of the cavity. These defects have been a factor that governs the service life of the dies and requires much time for repairing the dies.

[0007] There is a process of thixocasting for aluminum or other material where a gate is provided to prevent scale from mixing in the casting.

[0008] There is also such a thixocasting system for aluminum as the gate provided at the entry of the cavity to prevent scale from mixing in the casting is a sliding gate. In the sliding gate system, the gate is split into two halves, and the split gates can slide to the right and left to open and close, so that the gate is completed to be ready for injection casting when closed, and is in standby when opened.

[0009] Patent Document 1: Japanese Unexamined Patent Publication No. 8-300126

[0010] Patent Document 2: Japanese Unexamined Patent Publication No. 9-220656

[0011] Patent Document 3: Japanese Unexamined Patent Publication No.

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[0012] DISCLOSURE OF THE INVENTION

[0013] Problems to be Solved by the Invention

[0014] In case a thixocasting apparatus of slide gate system is applied to cast iron that is a material of high melting point, however, the high temperature tends to cause melting loss and/or cracks of the gate that may require frequent repairing of the die, or cause such a trouble that it becomes difficult to open/close the slide gate due to thermal strain.

[0015] Accordingly, an object of the present invention is to provide an apparatus for and a method of thixocasting a cast iron, that can effectively prevent the scale from mixing in the casting (cavity) thereby to obtain sound iron castings having good mechanical properties, by employing a system different from the slide gate system of the prior art.

[0016] Means for Solving the Problems

[0017] After various experiments and studies conducted in order to achieve the object described above, the present inventors have completed the invention of an apparatus for thixocasting a cast iron that employs a system called insert system, instead of the slide gate system. In the insert system, a plurality of gate members that are independent components are prepared as the gate, and are disposed at a cavity position every time injection casting is carried out. The gate member becomes inserted in the casting.

[0018] A first aspect of the apparatus for thixocasting a cast iron of the present invention is that at least a pair of dies that can freely open and close so as to form a cavity which is to be filled with semi-molten cast iron under a pressure, and injection means that injects the semi-molten iron into the cavity through an injection path are provided, while the gate is provided at the entry of the cavity so as to throttle the entry, wherein the gate is constituted from a separate gate member and is disposed at the entry of the cavity every time an injection casting operation is carried out and is taken out together with the casting after the injection casting operation.

[0019] A second aspect of the apparatus for thixocasting a cast iron of the present invention is that, in addition to the first aspect described above, the gate member has a

projecting portion formed around a gate hole that faces the injection path to a certain extent.

[0020] A third aspect of the present invention is a method of thixocasting a cast iron, which comprises filling the cavity in the dies with semi-molten cast iron injected under a pressure through the gate that throttles the entry of the cavity, wherein the injected material is covered on the circumference thereof with a thin steel sheet 0.2 to 0.5 mm thick that has a melting point higher than that of the injected material.

[0021] With the apparatus for thixocasting a cast iron according to the first aspect, when the material in semi-molten state is cast by injection by means of the injection means, one gate prepared in advance is disposed at the entry of the cavity formed by a pair of dies. Then the injection casting of the material is carried out by the injection means, so that the semi-molten material passes through the gate disposed at the entry of the cavity and fills the cavity under pressure, thereby to make a casting. At this time, the gate disposed at the entry of the cavity is integrated with the casting. After the casting operation, the pair of dies is opened and the gate is taken out together with the casting.

[0022] The gate removed with the casting can be recovered and reused by separating the portion soldified in the gate and the casting that has been in the cavity.

[0023] According to the apparatus for thixocasting a cast iron of the second aspect, since the gate is formed to have a projecting shape around the gate hole facing the injection path to a certain extent, at least the scale on the circumference of the injected material that is pressed against the gate is located outside the projecting portion, and is left behind without being injected through the gate hole into the cavity.

[0024] The term "certain extent" means such an extent around the gate hole as at least the scale formed on the circumference of the injected material is located at a position sufficiently far from the projecting portion. The projecting portion is preferably protrude by 2 mm or more.

[0025] According to the method of thixocasting a cast iron of the third aspect, since the injected material is covered on the circumference thereof with a thin steel sheet that has a melting point higher than that of the injected cast iron, the injected material is prevented from straining when heated into semi-molten state. There is also such an advantage that less scale is generated when heated into semi-molten state. Thickness of the thin steel sheet is within the range from 0.2 to 0.5 mm, because the effect of preventing the injected material from straining when heated into semi-molten state cannot be obtained when the thickness is less than 0.2 mm, and the thin steel sheet cannot be folded up well during the pressured injection operation and filling failure may result when the thickness is more than 0.5 mm. The thickness is preferably in a range from 0.2 to 0.3 mm.

[0026] The steel described above may be, for example, stainless steel.

[0027] Effect of the Invention

[0028] According to the apparatus for thixocasting a cast iron of claim 1, although the same number of the gate members are required as the number of castings to be made, since the gate is disposed at the entry of the cavity every time injection casting is carried out, the gate that receives the highest thermal load is replaced for each injection casting operation. As a result, melting loss and cracking of the gate can be prevented unlike in the slide gate system of the prior art.

[0029] In contrast to the slide gate system of the prior art that requires the use of beryllium copper or other expensive material, the gate made of a low-cost material such as spheroidal graphite cast iron can well endure melting loss and cracking according to the present invention.

[0030] In addition, since the die structure can be substantially simplified, the present invention is free from such a problem of the slide gate system that the slide gate becomes difficult to open and close due to thermal strain.

[0031] While the gate member of the present invention is integrated with the casting, the gate portion can be readily split from the casting since the cast iron is white cast iron in the case of the thixocasting, and therefore the gate can be taken away and reused.

[0032] According to the apparatus for thixocasting a cast iron of claim 2, in addition to the effect of the constitution of claim 1, since the gate has a projecting portion formed to a certain extent around the gate hole facing the injection path, most of the scale located at the distal end of the injected material such as a billet can be caused to stay in the space around the projecting portion. Also the presence of the projecting portion generates a force that presses the entire injected material against the circumference, so that the scale can be prevented from mixing on the circumference of the injected material. That is, the scale of the injected material can be effectively prevented from mixing into the cavity (casting).

[0033] According to the method of thixocasting a cast iron of claim 3, since the injected material is covered on the circumference thereof by the thin steel sheet that has a melting point higher than that of the injected cast iron, the injected material is

prevented from straining when heated into semi-molten state. When a part of relatively large size is cast, in particular, it is necessary to use the injected material such as a billet of a size that matches the size of the part to be cast and, accordingly, the injected material (billet) becomes more likely to strain by gravity as the injected material becomes larger. Thus it is not preferable to subject the semi-molten injected material that has strained to thixocasting process, since it causes the entrapment of scales.

[0034] Also by covering the injected material on the circumference thereof by the thin steel sheet that has a melting point higher than that of the injected cast iron, generation of the scale can be reduced when the injected material is heated into solid-liquid phase.

[0035] Also because the steel sheet used for covering is a thin sheet, the steel sheet is folded up in front of the gate when the injected material is injected under pressure, so that the scale formed on the injected material is captured by the folded steel sheet, thereby to prevent it from mixing in the cavity.

[0036] Brief Description of the Drawings

[0037] Fig. 1 is a longitudinal section view of an embodiment of the present invention.

[0038] Fig. 2 is a longitudinal section view of another embodiment of the present invention.

[0039] Description of Reference Numerals

10: Movable die

20: Fixed die

21: Fitting recess

22: Through hole

30: Plunger

40: Sleeve

41: Charge port

50: Gate member

51: Gate hole

52: Projecting portion

60: Cavity

70: Ejector pin

80: Injection path

B: Billet

[0040] BEST MODE FOR CARRYING OUT THE INVENTION

[0041] Preferred embodiments of the present invention will now be described in more detail with reference to the accompanying drawings.

[0042] With reference to Fig. 1, the apparatus comprises a pair of a movable die 10 and a fixed die 20, a plunger 30 and a sleeve 40 that constitute injection means and a gate 50.

[0043] The movable die 10 has a recess in the surface thereof that makes contact with the fixed die 20, the recess making a cavity 60. The movable die 10 has ejector pins 70 inserted therein for ejecting the casting the casting out of the die after casting.

[0044] The fixed die 20 has an injection path 80 formed therein that communicates with the sleeve 40. The fixed die 20 also has a fitting recess 21 where the gate 50 is fitted so as to be held on the surface in contact with the movable die 10. In communication with the fitting recess 21, a through hole 22 is provided as a part of the injection path 80.

[0045] The plunger 30 moves back and forth in the injection path 80, so as to push the semi-molten billet B that is the injected material forward as it advances, so as to fill in the cavity 60 with a pressure via the gate 50.

[0046] The sleeve 40 has a charge port 41 through which the billet B is fed into the injection path 80.

[0047] The injected material in the form of the billet B is cast iron, that is charged into the injection path 80 in semi-molten state through the charge port 41.

[0048] The gate may be made of, for example, spheroidal graphite cast iron, but may also be made of various low-cost metallic materials as long as the material would not be melted by the heat of the injection casting process. Ceramics may also be used. Since the gate 50 is used each every time injection casting is carried out, the material is required to be of low cost. In addition, such a material that is not susceptible to melting loss and cracking, and is suitable for separation from the casting when recovered and reused, so as to be favorably reused, may be used.

[0049] The gate member 50 has a through gate hole 51. Diameter of the gate hole 51 is made smaller than the diameter of the injection path 80, as a matter of course, and is smaller than the diameter of the billet B. The gate member 50 is fitted in the fitting recess 21 of the die so that the center of the gate hole 51 is located near the center of the cross section of the billet B to be injected.

[0050] The gate member 50 is fitted in the fitting recess 21 of the fixed die 20 before the pair of dies 10 and 20 are closed. The fitting action is carried out so that the gate 50 is reliably fastened in the state of the fixed die 20 and the movable die 10 being mated with each other, without mechanically connecting the gate member 50 and the fixed die 20.

[0051] The gate member 50 is disposed at the entry of the cavity 60 when the pair of dies 10 and 20 are closed (the state shown in Fig. 1), and the gate hole 51 of the gate member 50 serves as a throttled entry to the cavity 60. The billet B is injected through the gate hole 51 into the cavity 60.

[0052] Upon completion of the injection casting, the dies 10, 20 are opened and the casting is ejected from the cavity 60 by the ejector pins 70, so as to be taken out together with the gate 50.

[0053] The casting that has been taken out is integrated with the gate 50 by the material that is solidified in the gate hole 51. In the case of the thixocasting process cast iron, since the cast iron is white cast iron, the solidified portion of the gate member 50 can be readily split from the casting and therefore the gate 50 can be taken away and reused.

[0054] An embodiment shown in Fig. 2 is a variation of that shown in Fig. 1 with a different configuration of the gate member 50. With other regards, the two embodiments are the same and therefore description will be given with identical reference numerals shown in Fig. 2.

[0055] In the embodiment shown in Fig. 2, the gate 50 has a projecting portion 52 formed to a certain extent around the gate hole 51 of the gate member 50. The term "certain extent" means such an extent around the gate hole 51 as the scale formed on the circumference of the billet B is located at a position sufficiently far from the projecting portion 52. In order to cause most of the scale located at the distal end of the billet B to stay in the space around the projection 52, the certain extent described above is set to such a small distance around the gate hole 51 as the effect described above can be achieved.

[0056] The projecting portion is sized to about 2 mm to 10 mm.

[0057] By forming the projecting portion 52 around the gate hole 51 of the gate member 50, the scale formed on the billet B can be prevented from mixing (being entrapped) in the cavity 60.

[0058] In order to prevent the scale formed on the billet B from mixing in the cavity 60 during the thixocasting process of the cast iron, it is preferable to cover the circumference of the billet B with a thin sheet of steel that has a melting point higher than that of the billet B. Thickness of the thin steel sheet made be in a range from 0.2 to 0.5 mm, and preferably from 0.2 to 0.3 mm. The reason for setting this thickness has been described previously.

[0059] Functions of the thin steel sheet are to prevent the billet B from straining when heated, to reduce the scale generated on the surface of the billet B, and to become folded up in front of the gate member 50 when the injected material is injected, so as to capture the scale formed on the billet B by means of the folded thin sheet, thereby to prevent the scale from entering the gate hole 51.

[0060] Therefore, there is no limitation to the thickness of the thin sheet which may be such as can be folded up well at the time of injection casting, and that can sufficiently prevent the generation of the scale that would be formed on the surface of the billet B.

[0061] Examples

[0062] Table 1 shows chemical components of hypo-eutectic cast iron material used in the thixocasting process of an example. Both Examples and Comparative Examples used billets that were sampled from a continuously cast rod of the same batch, that

can be regarded as the same material without any substantial variation in the chemical composition.

[0063] Table 1

	Composition (% by weight)							
	C	Si	Mn	P	S	Ni	Cr	Fe
Billet	2.35	2.00	0.60	< 0.04	< 0.04	1.00	< 0.04	balance

[0064] The billet measures 75 mm in diameter, 150 mm in length and 5 kg in weight. The same casting conditions for the thixocasting operation were set for Examples and Comparative Examples, except for the injection rate, injection pressure and the billet heating temperature.

[0065] 20 test pieces were cast in each of Examples 1 to 6 and Comparative Examples 1 to 4.

[0066] In Examples 1 and 2, thixocasting process was carried out by using a flat gate member without projecting portion. In Examples 3 and 4, thixocasting process was carried out by using a gate member having a projecting portion. Examples 5 and 6 are Examples 1 and 2 plus a thin sheet of stainless steel having a thickness of 0.3 mm provided to cover the billet. In Comparative Examples 1 and 2, thixocasting process was carried out without using a gate member. In Comparative Examples 3 and 4, a

flat gate member without projecting portion is used and a thin sheet of stainless steel having a thickness of 0.6 mm provided to cover the billet.

[0067] Visual inspection and ultrasonic flaw detection test were employed to see whether the billet was strained when heated or not, whether the scale was entrapped after casting or not, and whether there were other defects.

[0068] Table 2 shows the conditions of injection casting, the number of castings that included scale entrapped therein, and the presence of other defects.

[0069] In the column "Scale entrapment defect" in Table 2, entry of "2P/20" indicates that defect was found in two out of the 20 test pieces.

[0070] Table 2

		Billet heating temperature (°C)	Gate member	Stainless steel film (mm)	Strain of billet	Scale entrapment defect	Other defects
Examples	1	1205	Flat	None	None	Present 2P/20	None
	2	1220	Flat	None	Present	Present 3P/20	None
	3	1205	Projecting shape	None	None	Present 1P/20	None
	4	1220	Projecting shape	None	Present	Present 2P/20	None
	5	1205	Flat	0.3	None	None	None
	6	1220	Flat	0.3	None	None	None
Comparative Examples	1	1205	No gate	None	None	Present 20P/20	Air entrapped
	2	1220	No gate	None	Present	Present 20P/20	Air entrapped
	3	1205	Flat	0.6	None	None	Gate hole clogged, filling defect
	4	1220	Flat	0.6	None	None	Filling defect

[0071] With reference to Table 2, Comparative Examples 1 and 2 are cases where injection casting was carried out without providing a gate member, and scale entrapment defect and air entrapment defect were found in all test pieces.

[0072] In Examples 1 and 2, a flat gate member without projecting portion was used without covering the billet, where entrapment of the scale was significantly reduced and other defects did not occur, although the billet strained when heated to 1220°C.

[0073] In Examples 3 and 4, a gate member having a projecting portion was used without covering the billet, where entrapment of the scale hardly occurred and other defects did not occur, although the billet strained when heated to 1220°C.

[0074] In Examples 5 and 6, a flat gate member without projecting portion was used while covering the billet with stainless steel sheet 0.3 mm thick, where entrapment of the scale and other defects did not occur, and the billet did not strain when heated to 1220°C.

[0075] Comparative Examples 3 and 4 are the same as Examples 5 and 6, except for covering the billet with the stainless steel sheet having a thickness of 0.6 mm. In case the billet was heated to 1205°C, the covering sheet blocked the gate hole resulting in filling defect. In case the billet was heated to 1220°C, there was a large resistance that strained the covering sheet, thus resulting in filling defect. Sheet thickness of 0.6 mm was too large.

[0076] INDUSTRIAL APPLICABILITY

[0077] The thixocasting process is capable of manufacturing a part that has a smaller wall thickness and more complicated shape than are possible with the conventional

iron casting processes. The thixocasting process can manufacture a part near net shape that has substantially no casting defects such as shrinkage cavity, and is therefore regarded as a promising new iron casting method.